Evaluation of Antioxidant Effects and Sensory Attributes of Chinese 5-Spice Ingredients in Cooked Ground Beef

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ABSTRACT: This study determined antioxidant and sensory characteristics of cinnamon, cloves, fennel, pepper, and star anise (Chinese 5-spice ingredients) in cooked ground beef. Total aerobic plate counts were also measured. Mean thiobarbituric acid (TBA) values were high (3.4 ppm) for control cooked ground beef samples. With 1% use level, all spice treatments had lower pooled mean TBA values than controls. At the lowest use level of 0.1% of meat weight, all spices except pepper had lower TBA values than controls. Treatments with 0.1% cloves had lower ($P < 0.05$) TBA values than 0.1% levels of other individual spices. Star anise, fennel, pepper, and cinnamon samples at 0.5% use level had lower mean TBA values than controls, but not different from 1.0% levels, respectively. Thus, the lowest effective spice level for cloves was 0.1% and 0.5% for the other spices. There was a high correlation ($P < 0.01$) between TBA values and panel scores for rancid odor and flavor (0.83 and 0.78, respectively). Spice flavor was inversely correlated ($P < 0.01$) with rancid odor and flavor (–0.57 and –0.61, respectively). The 5-spice blends did not affect microbial load of cooked samples compared with controls. In conclusion, all spices and blends had a dual effect, reducing rancid odor/flavor and imparting a distinctive flavor to cooked ground beef.

Keywords: Chinese 5-spice, antioxidant, ground beef

Introduction

The Chinese conceptualized the theory of "5 Elements" under which everything in our surroundings could be categorized into 5 basic elements. Chinese 5-spice is 1 application of the 5 elements theory. It was developed in an attempt to produce a powder that encompassed the 5 flavor elements: sweet, salty, sour, pungent, and bitter (Needham and Wang 1956). The traditional 5-spice mixture includes cinnamon, cloves, fennel, Szechwan pepper, and star anise. Today, however, Chinese 5-spice may also include ginger and nutmeg and can be easily obtained in any Asian market.

Lipid oxidation is 1 of the major causes of food deterioration. Lipid oxidation may also decrease nutritional value by forming potentially toxic products during cooking and processing (Shahidi and others 1992; Maillard and others 1996). Warmed-over flavor (WOF) is associated with cooked meat and intensifies during refrigerated storage (Tims and Watts 1958). Heating temperature affects the extent of lipid oxidation (Keller and Kinsella 1973). Ferric and ferrous iron ions catalyze the decomposition of lipid peroxides to more volatile aldehydes and ketones (McDonald and Hultin 1987). Early work showed that the meat pigment myoglobin had little or no catalytic effect on lipid oxidation in simple model systems or red meats (Sato and Hegarty 1971; Love and Pearson 1974). However, more recent work has shown lipid oxidation catalyzed by oxidized myoglobin species (Reeder and Wilson 2001), hemoglobin in fish muscle (Richards and Hultin 2002), and heme derived from myoglobin oxidation (Baron and Andersen 2002).

Compounds with antioxidant properties have been found in spices, oil seeds, citrus pulp and peel, and in products that have been heated and/or have undergone non-enzymatic browning. In addition to imparting distinctive flavors, spices contain antioxidant properties and inhibit rancid flavor development associated with lipid oxidation (Chipault and others 1952, 1955; Namiki 1990). Spices such as cloves, cinnamon, turmeric, black pepper, ginger, garlic, and onions exhibit antioxidant properties in different food systems (Younathan and others 1980; Al-Jalay and others 1987; Jurdi-Haldeman and others 1987). Spices have antioxidant properties due to the presence of compounds such as flavanoids, terpenoids, lignans, and polyphenolics (Craig 1999). However, their use may be limited in some foods due to their characteristic flavor and aroma. Use of unsterilized spices and herbs also increases the possibility of bacterial contamination in high-moisture foods (Garcia and others 2001).

Antioxidant compounds have been identified in all 5 components of Chinese 5-spice. Anise (*Pimpinella anisum* L.), nutmeg, and licorice all had strong hydroxyl radical (OH·) scavenging activity in deoxyribose assay (Murcia and others 2004). Fennel (*Foeniculum vulgare*) has in vitro antioxidant activity (Oktay and others 2003). The antioxidant compounds in fennel include 3-caffeoylquinic acid, rosamirinic acid, and quercetin-3-*O*-galactoside (Parejo and others 2004). Cloves (*Syzygium aromaticum*) contain eugenol and eugenyl acetate as the major aroma constituents. Both compounds inhibit hexanal formation (a product of lipid oxidation) in cod liver oil (Lee and Shibamoto 2001). Antioxidant activity in pepper (*Capsicum annum*) is due to presence of ascorbic acid, flavonoids, capasaicinoids, and phenolic acids (Jimenez and others 2003). Cinnamic aldehyde in cinnamon (*Cinnamomum aromaticum*) has potential antioxidant properties. Cinnamon and mint exhibited higher antioxidant properties than anise, ginger, licorice, nutmeg, or vanilla in a lipid peroxidation assay (Murcia and others 2004). A concentration of 500 μg/mL cinnamon extract inhibited hexanal production by 5% (Lee and Shibamoto 2002).

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Although the components of Chinese 5-spice have been shown to have antioxidant activity in model systems, our objective was to determine the optimum level of each spice for antioxidant properties in cooked ground beef. Sensory evaluation was also done on cooked ground beef containing various spices at their optimum (lowest effective) antioxidant level.

Materials and Methods

Experiment 1—Thiobarbituric acid (TBA) assay

The experiment was a completely randomized block design with 6 ground beef treatments (cinnamon, cloves, fennel, pepper, star anise, and retail 5-spice blend), at 4 levels (0%, 0.1%, 0.5%, and 1.0% of meat weight), 3 storage days (1, 8, and 15 d), and 3 replications of the entire experiment. TBA values (duplicates for each sample) were measured as an indicator of rancidity at 1, 8, and 15 d storage of cooked ground beef crumbles at 2 °C.

Treatment means were calculated by analysis of variance (ANOVA) using Statistica™ software (Statsoft Inc, Tulsa, Okla., U.S.A.). Significant differences among means were determined by calculation of Fisher's least significant difference (LSD) values. Significance was defined at $P < 0.05$ for ANOVA and LSD values.

The optimum or lowest effective spice level (0.1%, 0.5%, or 1%) for each individual spice was determined as the lowest spice concentration that resulted in TBA values significantly lower than the controls (0% spice). The 5 spices at their lowest effective levels were mixed to create the low clove 5-spice blend for sensory testing in experiment 2. The low clove 5-spice blend was created because cloves have strong flavor and odor that could be a concern with consumers. Thus, it was desirable to evaluate a blend with a clove proportion lower than 20% (the level if each of the 5 spices were present in equal proportions).

Experiment 2—Sensory evaluation

Cooked beef samples made with spices at their lowest effective levels as described in experiment 1 were evaluated for intensity of cooked beef flavor, rancid flavor/odor, and spice flavor intensity. A total of 10 treatments were evaluated (0.5% cinnamon, 0.1% cloves, 0.5% fennel, 0.5% pepper, 0.5% star anise, 0.5% retail 5-spice blend, 0.5% optimal 5-spice blend, rancid control, 0.5% sodium tripolyphosphate (STP) control, fresh control). The rancid control was cooked ground beef without added spices and held 15 d at 2 °C, allowing time to observe the full extent of oxidation in the controls compared with spice-treated samples. The fresh control was cooked ground beef without spices prepared on the day of the panel evaluation. Trained panelists ($n = 13$) evaluated samples after 15 d of storage at 2 °C. TBA values were measured on the samples that were served to the panelists. Treatment means were calculated by ANOVA as described in experiment 1. Correlation coefficients were calculated among sensory scores and TBA values. Significance was defined at $P < 0.01$ for correlation coefficients.

Experiment 3—Aerobic plate count

A 10-g portion of ground beef was mixed with 90 mL of sterile peptone water (Difco, Detroit, Mich., U.S.A.) in a dilution bottle, and plate counts were done on serial dilutions of cooked ground beef samples after 1, 8, or 15 d storage at 2 °C, following standard procedures (Messer and others 1978). Standard methods agar (Difco) was used as growth media. Duplicate plates were counted after incubation at 37 °C for 48 h.

Sample preparation

Ground star anise, fennel, cloves, and cinnamon (McCormick & Co. Inc., Hunt Valley, Md., U.S.A.), black pepper (Inter-American Foods Inc., Cincinnati, Ohio, U.S.A.), and lean ground beef (15% fat) were purchased at a local grocery. Retail Chinese 5-spice blend (Dynasty, San Francisco, Calif., U.S.A.) was also purchased locally. In addition to the 5 traditional spices, the retail blend also contained ginger and licorice. Each spice was manually mixed with ground beef (100 g/ treatment) at 0.1%, 0.5%, and 1.0% levels. Mixed samples were thoroughly cooked at 163 °C for 5 min, to a final temperature of 82 °C to 85 °C, as measured using a VersaTuff Plus 396 digital thermometer (Atkins Technical, Inc, Gainesville, Fla., U.S.A.) with a thin probe for fast response. The cooked ground beef crumbles were placed in resealable plastic bags, cooled for 10 to 15 min at room temperature, and stored for 1, 8, or 15 d at 2 °C. Thiobarbituric acid (TBA) values were measured in duplicate at 1, 8, or 15 d on the cooked samples as an indicator of oxidative rancidity. For each ingredient spice, the experiment was replicated 3 times. Duplicate sample analysis was performed. Thus, there were 6 observations per treatment.

TBA value

Thiobarbituric acid-reactive substances (TBARS) assay was performed as described by Buege and Aust (1978). Duplicate samples (0.5 g) for all the treatments were mixed with 2.5 mL of stock solution containing 0.375% TBA (Sigma Chemical Co., St. Louis, Mo., U.S.A.), 15% TCA (Mallinckrodt Baker Inc., Paris, Ky., U.S.A.), and 0.25 *N* HCl. The mixture was heated for 10 min in a boiling water bath (100 °C) to develop a pink color, cooled in tap water, and then centrifuged (Sorvall Instruments, Model RC 5B, DuPont, Wilmington, Del., U.S.A.) at 4300×g rpm for 10 min. The absorbance of the supernatant was measured spectrophotometrically (Spectronic 21D, Milton Roy, Rochester, N.Y., U.S.A.) at 532 nm against a blank that contained all the reagents except the meat. The malonaldehyde (MDA) concentration was calculated using an extinction coefficient of $1.56 \times 10^5/M/\text{cm}$ for the pink TBA-MDA pigment (Sinnhuber and Yu 1958). The absorbance values were converted to ppm malonaldehyde by using the following equations:

$$\text{TBA nr (mg/kg)} = \text{Sample } A_{532} \times (1\ M\ \text{TBA Chromagen}/156000) \times [(1\ \text{mole/L})/M] \times (0.003\ \text{L}/0.5\ \text{g meat}) \times (72.07\ \text{g MDA/mole MDA}) \times (1000\ \text{g/kg}) \quad (1)$$

$$\text{TBA nr (ppm)} = \text{Sample } A_{532} \times 2.77 \quad \text{(where MDA = malonaldehyde)} \quad (2)$$

Sensory evaluation

All panelists had previous sensory panel experience with cooked beef products. The panelists were trained in 2 sessions. In the 1st session, panelists were familiarized with the 5-point intensity scale and its usage. Panelists were also familiarized with cooked beef flavor (both fresh and rancid samples) and cooked ground beef with individual added spices (cinnamon, cloves, fennel, pepper, and star anise) and Chinese 5-spice blends at low (0.1%) and high (1%) spice concentrations. Group discussion was conducted regarding sample attributes. In the 2nd session, panelists again evaluated the same samples. The most consistent panelists ($n = 13$) were included in the final sensory panel.

Treatment samples were prepared with spice concentration at lowest effective levels of 0.5% for cinnamon, fennel, star anise, or black pepper, and 0.1% for clove (% raw meat weight) as determined in experiment 1 of this study. The low clove blend was 4.8% by weight cloves and 23.8% each of cinnamon, fennel, pepper, and star anise. Spice treatments were cooked, packaged, and stored as previously described. Three control cooked beef samples were also

Table 1—Summary of significance (*P* < 0.05) as determined by analysis of variance (ANOVA)

	n	TBA	*P* level
Treatment	72	*	0.0001
Spice Level	108	*	0.0001
D of storage	144	*	0.0001
Treatment × level	18	*	0.0001
Treatment × day	24	*	0.0001
Level × day	36	*	0.0001
Treatment × level × day	6	NS	0.1065

*Significant at *P* < 0.05; NS = not significant at *P* < 0.05; *n* = nr observations per mean.

Table 2—Mean thiobarbituric acid (TBA) values[a] for cooked ground beef formulated with the individual spices of Chinese 5-spice, at use levels of 0.1%, 0.5%, and 1.0% of raw meat weight[b]

Treatment	Spice level (% meat wt.)	TBA (ppm MDA)
Control	0.0	3.41 a
Cinnamon	0.1	1.66 cd
Cinnamon	0.5	0.76 e
Cinnamon	1.0	0.78 e
Cloves	0.1	0.76 e
Cloves	0.5	0.96 de
Cloves	1.0	0.88 e
Fennel	0.1	2.32 bc
Fennel	0.5	1.39 de
Fennel	1.0	0.99 de
Pepper	0.1	2.87 ab
Pepper	0.5	1.28 de
Pepper	1.0	1.26 de
Star anise	0.1	2.55 b
Star anise	0.5	0.97 de
Star anise	1.0	0.71 e
Retail 5-spice	0.1	0.99 de
Retail 5-spice	0.5	0.73 e
Retail 5-spice	1.0	1.00 de
LSD	0.05	0.76

[a]Mean TBA values with the same letter are not different (*P* < 0.05).
[b]Means were pooled for storage time (1, 8, and 15 d) after cooking (*n* = 18).

prepared. The controls were (1) fresh, (2) STP, and (3) rancid. Fresh control samples were cooked immediately before serving, using lean ground beef (15% fat) purchased locally on the d of the panel. STP controls were formulated with 0.5% STP, cooked and refrigerated for 15 d. Rancid controls were cooked samples without STP or spice and refrigerated for 15 d. TBA values were measured for all controls and treated samples on the same day as the panel evaluation.

The 7 treatment samples at optimal concentrations and 3 controls of cooked beef crumbles were evaluated in 3 sessions. A set of 5 or 6 samples (6 g each) was served to each panelist in each session, consisting of 2 or 3 spice-treated samples and 3 controls. Samples were coded and microwave reheated for 25 s to attain a temperature of 80 °C to 85 °C immediately before serving. Samples were evaluated in individual booths under red lights. The serving order was randomized to avoid positional bias.

Panelists were asked to evaluate samples for intensity of rancid odor, rancid flavor, beef flavor, and spice flavor on a 5-point scale, where 1 = no flavor or odor, 2 = slightly intense, 3 = moderately intense, 4 = very intense, and 5 = extremely intense flavor or odor. Panelists were also asked to provide additional qualitative comments for each sample. Before evaluating the next sample, ballot instructions specified that the previous sample be expectorated into cups provided for that purpose. Panelists were instructed to rinse their mouth with tap water. Unsalted crackers were also provided to cleanse the palate.

Results and Discussion

Experiment 1—TBA assay of cooked ground beef with individual spices

Main effects of treatment (cinnamon, cloves, fennel, pepper, star anise, retail 5-spice blend), spice level (0%, 0.1%, 0.5%, 1.0%), and day of refrigerated storage (1, 8, 15 d) significantly affected the TBA values of cooked ground beef (Table 1). All 2-way interactions also affected ($P < 0.05$) TBA values, but the 3-way interaction of treatment × spice level × day storage did not significantly affect TBA values (Table 1).

Cooked ground beef mean TBA values for the 2-way interaction of spice treatment × level are shown in Table 2. Mean TBA values were high (3.4) for control cooked ground beef samples. With 1% use level, all spice treatments had lower ($P < 0.05$) TBA values than controls. At the lowest use level of 0.1% of meat weight, all spices except pepper had lower TBA values than controls, and clove treatments had lower ($P < 0.05$) TBA values than other spices. Mean TBA value for the 0.1% clove treatment was 0.76, compared with 1.66, 2.32, 2.87, and 2.55 for 0.1% cinnamon, fennel, pepper, and star anise, respectively (Table 2).

Thus, the optimum or lowest effective spice level for cloves was 0.1% and 0.5% for the other spices, where lowest effective spice level was defined as the lowest spice weight/100 g meat (0.1, 0.5, or 1.0) that had significantly lower TBA values than other levels (Table 2). After 15 d of refrigerated storage, TBA values were as high as 5.9 for controls without added spice, compared with 0.79, 0.75, 2.22, 1.70, 1.30, and 0.37 for 0.5% cinnamon, 0.1% cloves, 0.5% fennel, 0.5% pepper, 0.5% star anise, and 0.5% 5-spice blend (lowest effective levels, respectively; Figure 1 to 6).

TBA values >1.0 are usually associated with rancid flavor/odor by sensory panelists (Tarladgis and others 1960; Jayasingh and Cornforth 2003). Note that TBA values of clove-treated ground beef samples (Figure 2) remained less than 1.0 for the entire 15-d storage period as did the samples with 0.5% or 1.0% retail 5-spice blend (Figure 6). Ground beef with 1.0% fennel or 0.5% to 1.0% pepper had TBA values <1.1 for 8 d storage (Figure 3 and 4). Ground beef with 1.0% cinnamon or 1.0% star anise had TBA values <1.0 for 15 d storage (Figure 1 and 5). Thus, treatment with cloves was clearly the most effective among individual spices for maintenance of low TBA values of cooked ground beef during refrigerated storage.

The antioxidant effects of cinnamon, clove, fennel, pepper, and star anise in this study are in agreement with previous findings by others. Cinnamon essential oil has been shown to have significant antioxidant activity in Chinese-style sausages (Ying and others 1998). Cloves at 0.05% were shown to enhance the storage stability and acceptability of frozen stored fish mince for about 28 wk. For 50-wk storage, a use level of 0.1% was optimal (Joseph and others 1992). Clove powder at 0.2% w/w significantly reduced oxidative rancidity measured by TBARS, and improved acceptability of oysters. The oysters remained acceptable for 278 d when treated with cloves compared with 235 and 237 d for butylated hydroxytoluene (BHT)-treated and untreated samples, respectively (Jawahar and others 1994). Clove and Maillard reaction products have been shown to inhibit the increase of secondary oxidation products formed during refrigerated storage of cooked meat and to affect the extent of non-heme iron release during cooking, which is believed to be the primary catalyst accelerating lipid oxidation (Jayathikalan and others 1997). Black pepper was an effective sensory flavoring agent in chicken feet (Jokpyun, a traditional Korean gel type delicacy) at the 0.33% level, based on response surface methodology (Mira and others 2000). Ground black pepper oleoresin extracted by supercritical carbon dioxide was more effective in reducing lipid oxidation of cooked ground pork than oleoresin extracted by conventional methods (Tiprisukond and others 1998). Star anise was effective at 0.5% level based on meat weight. Anise-treated samples had a TBA value of 0.97. Anise has also been shown to have antioxidant effects in Chinese marinated pork shanks as compared with controls (Tzu and others 1997).

Experiment 2—sensory evaluation

Mean trained panel sensory scores and thiobarbituric acid

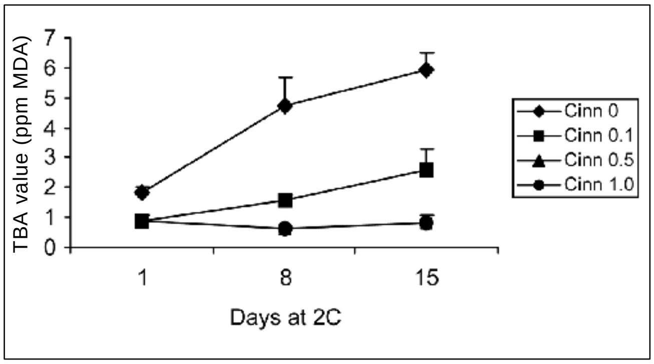

Figure 1—Effect of cinnamon concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). Mean values differing by more than 0.94 are significantly different. $LSD_{0.05}$ = 0.94.

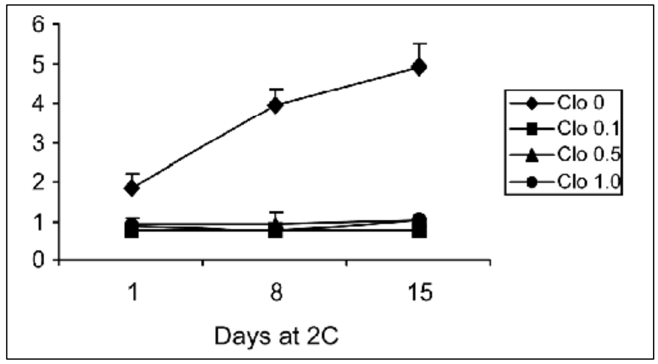

Figure 2—Effect of clove concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). $LSD_{0.05}$ = 0.94.

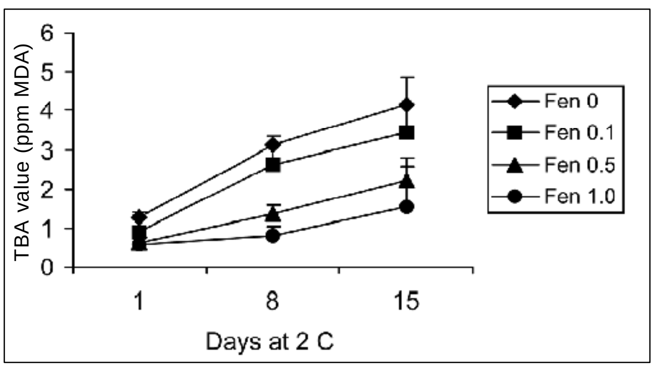

Figure 3—Effect of ground fennel concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). $LSD_{0.05}$ = 0.94.

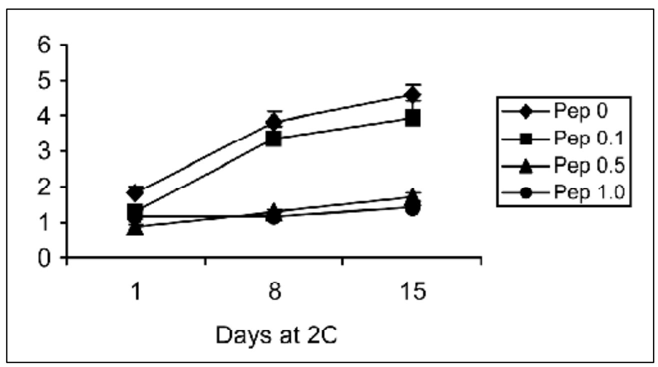

Figure 4—Effect of pepper concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). $LSD_{0.05}$ = 0.94.

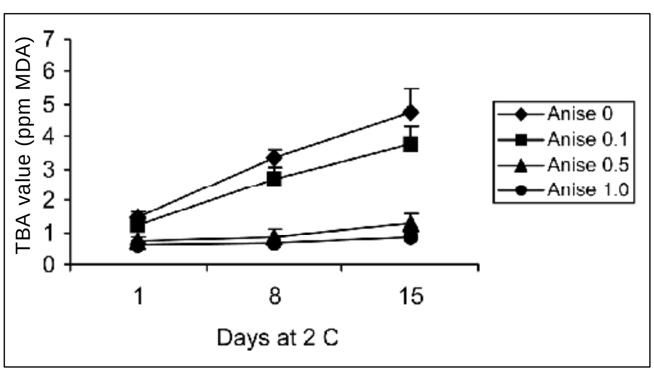

Figure 5—Effect of star anise concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). $LSD_{0.05}$ = 0.94.

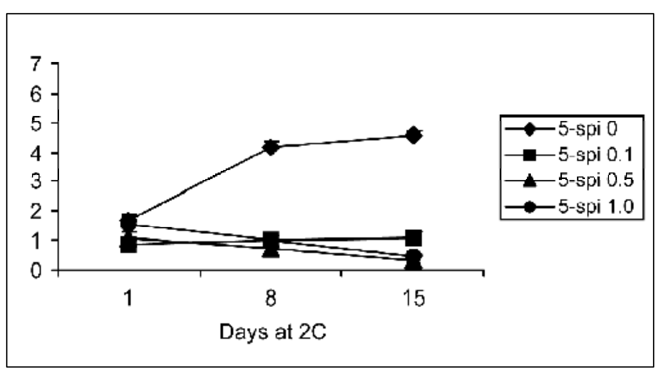

Figure 6—Effect of retail Chinese 5-spice concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). $LSD_{0.05}$ = 0.94.

Table 3—Mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles after 15 d storage at 2 °C. Lowest effective spice levels were used as determined from Table 1.[a]

Treatment	Use level (% meat weight)	Rancid odor	Rancid flavor	Beef flavor	Spice flavor	TBA value	Qualitative comments
Rancid control	0.0	3.3 a	3.4 a	2.0 b	1.0 d	7.2 a	Rancid, painty, stale
STP control	0.5	1.4 b	1.4 b	3.0 a	1.1 d	0.3 f	Beefy, salty
Fresh control	0.0	1.5 b	1.5 b	3.2 a	1.1 d	1.0 de	Steak –like, oily, beefy
Cinnamon	0.5	1.1 b	1.1 b	1.7 b	2.9 bc	1.6 cd	Cinnamon flavor, spicy
Cloves	0.1	1.0 b	1.1 b	2.2 b	3.1 bc	0.4 e	Strong clove flavor, smells like dentist's office
Fennel	0.5	1.5 b	1.6 b	1.9 b	3.1 bc	5.5 b	Licorice flavor, spicy
Pepper	0.5	1.4 b	1.2 b	2.1 b	3.2 ab	1.6 cd	Peppery, hot
Star anise	0.5	1.2 b	1.1 b	1.8 b	3.9 a	1.9 c	Licorice flavor, spicy
Retail 5-spice blend	0.5	1.0 b	1.2 b	1.9 b	3.3 ab	0.7 ef	Strong spicy, black licorice
Low clove-spice blend	0.5	1.3 b	1.2 b	2.1 b	2.4 c	1.0 de	Spicy
LSD	0.5	0.52	0.52	0.68	0.74	0.66	

[a]Mean values within a column with the same letter are not different ($P < 0.05$)

(TBA) values of spice-treated, cooked ground beef crumbles after 15 d storage at 2 °C are shown in Table 3. The control samples without added spices (rancid control) had the highest scores for rancid odor and flavor intensity and also the highest TBA values (7.2). The control samples made with 0.5% sodium tripolyphosphate (STP control) had low scores for rancid odor, flavor, and spice flavor intensity, and also had lowest TBA value of 0.3. This observation is in agreement with previous work showing that phosphate compounds such as sodium tripolyphosphate (STP) or milk mineral are quite effective antioxidants in cooked ground meats, due to their ability to bind ionic iron and thus prevent iron catalysis of lipid oxidation (Cornforth and West 2002; Jayasingh and Cornforth 2003). The control samples without spices, and prepared on the day of the panel evaluation (fresh control) also had low scores for rancid odor, flavor, and spice flavor intensity, and had a relatively low TBA value of 1.0. All cooked ground beef samples made with spices (cinnamon, cloves, fennel, pepper, and star anise) had lower ($P < 0.05$) scores for rancid odor and flavor, and lower ($P < 0.05$) TBA values, compared with the control without spices (rancid control), but similar to the low TBA values of the controls with STP. Previous work on antioxidant mechanism of spices in model systems has identified various phenolic compounds that are type 1 antioxidants, capable of interruption of the initiation and propagation steps of lipid oxidation by donation of hydrogen (H·). However, one cannot rule out the possibility that the fiber component of spices may bind ionic iron in cooked meat systems, and thus behave as type 2 antioxidants such as STP.

Beef samples made with spices also had lower ($P < 0.05$) beef flavor intensity scores, and higher ($P < 0.05$) spice flavor intensity, compared with fresh or STP controls. Among the 5 individual spice treatments, samples made with star anise had a higher ($P < 0.05$) spice flavor intensity than samples made with cinnamon, cloves, or fennel. 5-spice blends (retail or optimum) effectively lowered ($P < 0.05$) rancid odor, rancid flavor, and TBA values of stored, cooked ground beef samples compared with treatments without added spices (rancid controls). The retail 5-spice blend had significantly higher ($P < 0.05$) spice flavor intensity than the low clove blend, perhaps because the retail blend contained ginger and licorice in addition to the traditional 5 spices. Panel comments indicated that spices imparted characteristic flavors to the samples. For instance, cinnamon-treated samples tasted like cinnamon and samples with black pepper tasted peppery. The control without added spices was described as painty, stale, or rancid. The control with STP was described as beefy and salty, whereas the fresh control was beefy or oily. The retail 5-spice treatment had licorice or spicy flavor, whereas the optimum (low clove) blend was described as spicy (Table 3). In this study, the trained panel provided precise information on intensity of various flavors, with no indication of acceptability. One may infer, however, that samples with high scores for rancid flavor would be unacceptable to most consumers. Conversely, samples with moderate spice flavor intensity would be acceptable to many people. Some panelists commented that some samples were "too hot" or "too spicy," indicating a dislike for higher spice levels (Table 3).

Table 4—Correlation coefficients (*r*) among mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles after 15 d storage at 2 °C

	Rancid odor	Rancid flavor	Beef flavor	Spice flavor	TBA value
Rancid odor	1.00	—	—	—	—
Rancid flavor	0.98*	1.00	—	—	—
Beef flavor	0.03	0.05	1.00	—	—
Spice flavor	–0.57*	-0.61*	-0.60*	1.00	—
TBA value	0.83*	0.78*	–0.31	–0.21	1.00

*$P < 0.01$.

Correlation coefficients among mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles are shown in Table 4. There was a high correlation ($P < 0.01$) between TBA values and panel scores for rancid odor and flavor (0.83 and 0.78, respectively). Not surprisingly, a very high correlation (0.98) was observed between rancid flavor and rancid odor. There was a significant inverse relationship between spice flavor and beef flavor, indicating that samples with added spice did not retain a typical cooked ground beef flavor. Spice flavor was inversely correlated ($P < 0.01$) with rancid odor and flavor (–0.57 and –0.61, respectively). Thus, samples with added spice tended to lose their beef flavor but did not taste rancid.

Experiment 3—aerobic plate count

Aerobic plate counts were done after 1, 8, or 15 d of storage at 1 °C of cooked ground beef samples made with 0.5% retail 5-spice, 0.5% optimum 5-spice, or controls without spice. Log_{10} mean aerobic plate counts pooled over storage time were 4.1, 4.1, and 3.9, respectively, and were not significantly different, which is not unusual for cooked samples. There were no significant treatment × time interactions for aerobic plate counts. Thus, addition of 0.5% spice blends had no antimicrobial effects during storage of cooked ground beef in this study. Spices and essential oils are known to exhibit antimicrobial effects in various food products or model systems (Yuste and Fung 2002; Guynot and others 2003; Ozkan and others 2003). The lack of antimicrobial effects in cooked ground beef during storage in this study may be due to heat inactivation or loss of antimicrobial components during cooking.

Conclusions

All spices imparted a distinctive flavor to the cooked ground beef and had marked antioxidant properties. These traditional spices do not simply mask the rancid off-flavors but rather have antioxidant effects.

Acknowledgments

The authors gratefully acknowledge the financial support of the Utah Agricultural Experiment Station in support of this study. Utah Agricultural Experiment Station journal paper nr 7651.

References

Al-Jalay B, Blank G, McConnell B, Al-Khayat M. 1987. Antioxidant activity of selected spices used in fermented meat sausage. J Food Prot 50:25–7.
Baron CP, Andersen HJ. 2002. Myoglobin-induced lipid oxidation–a review. J Agric Food Chem 50:3887–97.
Beuge JA, Aust SD. 1978. Microsomal lipid peroxidation. Meth Enzymol 52:302–4.
Chipault JR, Mizuna GR, Hawkins JM, Lundberg WO. 1952. The antioxidant properties of natural spices. Food Res 17:47–55.
Chipault JR, Mizuna GR, Hawkins JM, Lundberg WO. 1955. The antioxidant properties of spices in foods. Food Technol 10:209–11.
Cornforth DP, West EM. 2002. Evaluation of the antioxidant effects of dried milk mineral in cooked beef, pork, and poultry. J Food Sci 67(2):615–8.
Craig JW. 1999. Health-promoting properties of common herbs. Am J Clin Nutr 70:491S–9S.
Garcia S, Iracheta F, Galvan F, Heredia N. 2001. Microbiological survey of retail herbs and spices from Mexican markets. J Food Prot 64(1):99–103.
Guynot ME, Ramos AJ, Seto l, Puroy, P, Sanchis V, Marin S. 2003. Antifungal activity of volatile compounds generated by essential oils against fungi commonly causing deterioration of bakery products. J Appl Microbiol 94(5):893–9.
Jawahar AT, Balasundari S, Indra JG, Jeyachandran P. 1994. Influence of antioxidants on the sensory quality and oxidative rancidity of frozen edible oyster. J Food Sci Technol India 31(2):168–70.
Jayasingh P, Cornforth DP. 2003. Comparison of antioxidant effects of milk mineral, butylated hydroxytoluene and sodium tripolyphosphate in raw and cooked ground pork. Meat Sci 66:83–9.
Jayathikalan K, Vasundhara TS, Kumudavally KV.1997. Effect of spices and Maillard reaction products on rancidity development in precooked refrigerated meat. J Food Sci Technol India 34(2):128–31.
Jimenez A, Romojaro F, Gomez JM, Llanos MR, Sevilla F. 2003. Antioxidant systems and their relationship with the response of pepper fruits to storage at 20 °C. J Agric Food Chem 51(21):6293–9.
Joseph J, George C, Perigreen PA. 1992. Effect of spices on improving the stability of frozen stored fish mince. Fishery Technol 29(1):30–4.
Jurdi-Haldeman D, MacNeil JH, Yared DM. 1987. Antioxidant activity of onion and garlic juices in stored cooked ground lamb. J Food Prot 50:411–3.
Keller JD, Kinsella JE. 1973. Phospholipid changes and lipid oxidation during cooking and frozen storage of raw ground beef. J Food Sci 38:1200–4.
Lee KG, Shibamoto T. 2002. Determination of antioxidant potential of volatile extracts isolated from various herbs and spices. J Agric Food Chem 50(17):4947–52.
Lee KG, Shibamoto T. 2001. Antioxidant property of aroma extract isolated from clove buds [Syzygium aromaticum (L) Merr. Et Perry]. Food Chem 74:443–8.
Love JD, Pearson AM. 1974. Metmyoglobin and non-heme iron as proxidants in cooked meat. J Agric Food Chem 22(6):1032–4.
Maillard MN, Soum MH, Boivin P, Berset C. 1996. Antioxidant activity of barley and malt—Relationship with phenolic content. Lesbensm Wissen 29:238–44.
McDonald RE, Hultin HO. 1987. Some characteristics of enzymic lipid peroxidation systems in the microsomal fraction of flounder muscle. J Food Sci 52:15–21, 27.
Messer JW, Peeler JT, Gilchrist JE. 1978. Aerobic plate count. In: FDA bacteriological analytical manual. 5th ed. Ch. 4. Washington, D.C.: AOAC. Ch IV, p 1-10.
Mira J, Sang SO, Kwang OK. 2000. Effects of levels of flavoring materials on the sensory properties of chicken feet jokpyun (Korean traditional gel type food). Korean J Food Sci Technol 32(6):1306–12.
Murcia AM, Egea I, Romojaro F, Parras P, Jimenez AM, Martinez-Tome M. 2004. Antioxidant evaluation in dessert spices compared with common food additives. Influence of irradiation procedure. J Agric Food Chem 52(7):1872–81.
Namiki M. 1990. Antioxidants/antimutagens in foods. Crit Rev Food Sci Nutr 29:273–300.
Needham J, Wang L. 1956. Science and civilization in China. Vol. 2. London: Cambridge Univ. Press. p 262–3.
Oktay M, Gulçin I, Kufrevioglu OI. 2003. Determination of in vitro antioxidant activity of fennel (Foeniculum vulgare) seed extracts. Lebensm Wissen 36:263–71.
Ozkan G, Sagdic O, Ozcan M. 2003. Inhibition of pathogenic bacteria by essential oils at different concentrations. Food Sci Technol Int 9(2):85–8.
Parejo I, Viladomat F, Bastida J, Schmeda-Hirschmann G, Burillo J, Codina C. 2004. Bioguided isolation and identification of the nonvolatile antioxidant compounds from Fennel (Foeniculum vulgare Mill.) waste. J Agric Food Chem 52(7):1890–7.
Reeder BJ, Wilson MT. 2001. The effects of pH on the mechanism of hydrogen peroxide and lipid hydroperoxide consumption by myoglobin: a role for the protonated ferryl species. Free Rad Biol Med 30(11):1311–8.
Richards MP, Hultin HO. 2002. Contributions of blood and blood components to lipid oxidation in fish muscle. J Agric Food Chem 50:555–64.
Sato K, Hegarty GR. 1971. Warmed-over flavor in cooked meats. J Food Sci 36:1098–102.
Shahidi F, Janitha PK, Wanasundara PD. 1992. Phenolic antioxidants. Crit Rev Food Sci Nutr 32 :67–103.
Sinnhuber RO, Yu TC. 1958. 2-Thiobarbituric acid method for the measurement of rancidity in fishery products. II. The quantitative determination of malonaldehyde. Food Technol 12(1):9–12.
Tarladgis BG, Watts BM, Younathan MT, Dugan L. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J Am Oil Chem Soc 37:44–8.
Tims MJ, Watts BM. 1958. Protection of cooked meats with phosphates. Food Technol 12:240–3.
Tiprisukond N, Fernando LN, Clarke AD. 1998. Antioxidant effects of essential oil and oleoresin of black pepper from supercritical carbon dioxide extractions in ground pork. J Agric Food Chem 46(10):4329–33.
Tzu YW, Ming TC, Deng CL, Shiu LG. 1997. Effect of procedure, spice, herb and anka rice on the quality of Chinese marinated and spiced pork shank. J Chinese Soc Animal Sci 26(2):211–22.
Ying RY, Ming TC, Deng CL. 1998. A study of antioxidative and antibacterial effects of different spices in Chinese-style sausage. J Chinese Soc Animal Sci 27(1):117–28.
Younathan MT, Marjan ZM, Arshad FB. 1980. Oxidative rancidity in stored ground turkey and beef. J Food Sci 45:274–5.
Yuste J, Fung DYC. 2002. Inactivation of *Listeria monocytogenes* Scott A 49594 in apple juice supplemented with cinnamon. J Food Prot 65(10):1663–6.